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Collembola as indicators for long-term effects of intensive management

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Because hops is cultivated without rotation, pesticides, especially heavy metals, accumulate in the soil. Collembola were monitored for two years in hop fields on loam or sand soil and fertilized with mineral fertilizers or additional green manure. The use of copper and sulfur fungicides was accompanied by a decrease in Collembola populations.

1. Introduction

The cultivation of hops is one of the most intensive agricultural activities practised in Germany. Similar to vine, the crops stand for many years without rotation. Thus, they are very susceptible to pests and treated with pesticides at least seven times a year. Since in most cases copper fungicides are used, their application leads to high contamination of the soil. Collembola are very common in arable soils, and former investigations (Filser 1992) have shown that in hops they are of great importance among soil fauna. Because of their large ecological relevance and their high sensibility against harmful substances they have often been objects of ecotoxicological research, mainly dealing with pesticides (e.g. Tomlin 1975, Fratello et al. 1985). Effects caused by heavy metals mostly have been investigated in connexion with contaminated soils near metallurgical works (Posthuma 1992) or with sewage sludge (Lübben & Larink 1990), also laboratory studies were carried out (Bengtsson et al. 1983, Van Straalen & Van Meerendonk 1987). The aim of this study was to find out if the combined effects of long-term intensive management influence Collembola populations negatively.

2. Sites and methods

During 1989 and 1990 the dynamics of Collembola in four hop fields were studied. Two soil types and two cropping systems were selected (Tables 1, 2). Within the text, the following abbreviations are used: L (loam), S (sand), M (only mineral fertilizers), and G (additional green manure). Each plot had a size of 0.1 ha. The samples were taken at random in the rows between the plants, with ten replicates each. The stainless steel cylinders used had a volume of 200 cm^3 (diameter 78 mm, height 40 mm). The soil fauna was extracted by a modified MacFadyen-High-Gradient-Extractor. Ethylene glycol was used as collection fluid. The Collembola were warmed in lactic acid, prepared with Marc André No. 2 and measured under a microscope. Based on body length biomass was calculated according to Dunger (1968).

During harvest 1989, the leaves of three comlete hop plants were taken from LM. After air-drying, they were grinded and dissolved with conc. HNO_3/HCl (1:3). Heavy metals were determined by atomic emission spectroscopy.

3. Results and discussion

From July 1989 to April 1990 there were no large differences in total Collembola biomass (Fig. 1). During the last five months of the investigation, an increase of biomasses up to the seven-fold level (compared with April) was observed in three fields, whereas in LM the population nearly collapsed. There are several explanations for this phenomenon:

1. Copper concentration was highest in LM and also much higher in loam than in sand (Table 1). Contrarily, biomass of Collembola in sand was distinctly larger than in loam.
2. In LM in both years of investigation copper fungicides were used three times. In LG, copper applications had been reduced since 1988. Probably this is why the copper content in this soil was distinctly lower than in

LM, and the Collembola population was able to increase again. Some Collembola species are able to tolerate heavy metals to a certain extent by genetic adaptation (Posthuma 1992), but also negative effects have been described (Bengtsson et al. 1983, Lübben & Larink 1990, Van Straelen & Van Meerendonk 1987).

3. LM was the only field in which sulfur fungicides were applied. Talbot (1987) describes insecticidal effects of sulfur on Collembola. From previous investigations of four other hop fields (Filser 1993) the smallest Collembola population by far was found in a field with a very high copper content (136 μg/g, 0–30 cm), and which was the only one to be treated with sulfur fungicides.
4. In September 1990, in LM crop residues of hops (consisting of 50% leaves and 50% stalks) were brought out. Especially the leaves contained very large amounts of heavy metals (Cd 0.12, Cu 983.3, Hg 0.15, Ni 1.5, Pb 2.9, and Zn 43.9 μg/g plant dry weight, $SE \leq 5\%$). Collembola mainly feed on dead plant material or on fungi growing on decaying organic matter. Thus, they are directly exposed to toxic heavy metal concentrations. Because of their narrow C:N ratio (10:1) hop leaves should be a diet especially preferred by Collembola (Dunger 1956). In contrast to this, litterbag studies with hop leaves have shown that they are not settled by Collembola over a longer period if there are alternative food sources (Kallhardt 1991).

Usually populations of Collembola in hops are not smaller than in other cropping systems (cf. Filser 1993). In some places with hops grown for a very long time Collembola biomasses are extremely low. One possible explanation for that phenomenon is an intoxication by residues of inorganic fungicides.

Table 1. Properties of experimental fields. Data from 0–10 cm. All specifications refer to soil dry weight. Data from Winter 1990.

Soil type	Colluvial cambisol derived from loess		Gleysol derived from callow sands	
Texture (0–30 cm)	Clay 25%, silt 62%, sand 14%		Clay 14%, silt 25%, sand 63%	
Experimental field	LG	LM	SG	SM
Water holding capacity, max (%)	56	58	54	58
pH ($CaCl_2$)	7.2	7.1	5.2	6.4
Carbon content (%)	1.98	2.28	3.39	2.62
Nitrogen content (%)	0.21	0.25	0.31	0.25
Carbon/nitrogen	9.5	9.1	11.1	10.6
Copper, total content (mg/kg)	206.0	320.3	49.6	32.0

Table 2. Table of management. All fields were ploughed, cultivated, and received mineral fertilizers. Pesticides: mean annual amounts of applications.

	LG	LM	SG	SM
Cultivation of hops since	1950	1967	1978	1983
Organic	FYM3		FYM3	
fertilization (1)	CR 3	CR 6	CR 3	
Greeen manure	Rape		Rape	
Herbicides (2)	AHL [40]		AHL [40]	
	1 x Reglone	1 x Reglone	1 x Reglone	1 x Reglone
Fungicides (3)	2 x Cu	1 x Cu	3 x Cu	3 x Cu
	3 x sys	1 x sys	6 x sys	1 x sys
	1 x orgF	2 x orgF	1–2 x orgF	1–2 x orgF
		3 x Cu/S		
Insecticides (4)	Pyr**	Pyr**	Pyr**	Pyr**
				1 x PE
	Car**	Car**	Car**	Car**
	ES**	ES**	ES**	ES**
Acaricides	0–1 x	0–1 x		0–1 x

1) FYM = Farmyard manure, CR = Crop residues, 3,6 = every 3 or 6 years, resp.
2) AHL = concentrated nitrogene solution [kg N/ha]
3) Cu (/S) = copper (+ sulfur) fungicides, sys = systemic fungicides, orgF = organic fungicides against Sphaerotheca
4) Pyr = pyrethroids, PE = phosphoric acid ester, Car = carbamates, ES = endosulfane
** = changing substances, altogether 2 treatments/year

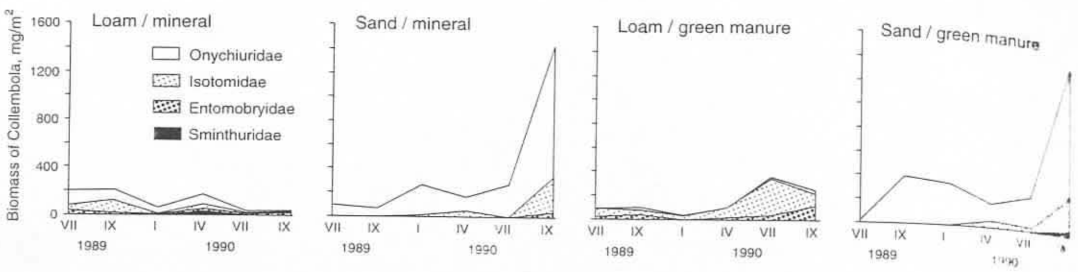

Fig. 1. Temporal development of Collembola biomass in the upper 4 cm of the soil. The ordinate refers to total biomass, the differently hatched areas show the relative contributions of single families.

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